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Principles of Ubiquitous Computing

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Outline

- History
- Mark Weiser's vision
- Principles according to Weiser
- Building blocks of ubiquitous computing
- Dangers
- Art or science? Or both?
- Conclusion

Once upon a time in a galaxy far, far away…

- Mainframes dominated the computing scene: computers were BIG things
  - Multi-user systems
  - Dumb consoles for end-user access
- Dedicated places for computers, “computer room”, “mainframe room”, “control room”, etc.

Once upon a time in a galaxy far, far away...

- Computers were not for everyone:
  - Operating the computers required highly trained personnel
  - Human-computer interfacing on computer's terms: lack of user-friendliness
  - Computers were VERY expensive, thus out of reach of the ordinary person

Developments from the past to present 1/3

- Appearance of the **personal** computer (PC)
- Computational power has grown dramatically
- Computers have become much smaller, small enough to carry them with you
- Improved network technologies: wired, wireless bandwidth have increased

Developments from the past to present 2/3

- Client-server to peer-to-peer
  - Wireless peer-to-peer means not having to rely on existing infrastructure, allows ad-hoc networking
- User interfaces have gotten much better
- From text mode UIs to mouse-operated windowing systems and even more exotic interfaces

Developments from the past to present 3/3

- Computing devices are appearing in new places:
  - Refrigerators, ovens, coffee machines
  - Cars
  - Washing machines
  - Vacuum cleaners
  - Shoes (e.g. Adidas)

The big trend

Computation is becoming ubiquitous.

Computing devices have started to pervade our lives.

Mark Weiser (1952-1999)

- Weiser's seminal papers started the field of ubiquitous computing
- Chief scientist at Xerox Palo Alto Research Center (PARC)
- "*...highest ideal is to make a computer so imbedded, so fitting, so natural, that we use it without even thinking about it*" (Weiser)

Weiser on ubiquitous computing

"*Ubiquitous computing names the third wave in computing, just now beginning. First were* ***mainframes****, each shared by lots of people. Now we are in the* ***personal computing*** *era, person and machine staring uneasily at each other across the desktop. Next comes* ***ubiquitous computing****, or the age of calm technology, when technology recedes into the background of our lives.*" (Weiser, emphasis added)

Principles of ubiquitous computing

- “The purpose of a computer is to help you do something else.”
- “The best computer is a quiet, invisible servant.”
- “The more you can do by intuition the smarter you are; the computer should extend your *unconscious*.”
- “Technology should create **calm**.”
  - Calm technology is “that which informs but doesn't demand our focus or attention” (Weiser, Brown)

Example of calm technology

- “Dangling string” by Natalie Jeremijenko
- 8-foot (2.4 m) piece of plastic spaghetti attached to an electrical motor, hanging from the ceiling
- Weiser, Brown: Designing Calm Technology, Xerox PARC, 1995.

The dangling string

- The motor makes the string whirl based on network traffic intensity:
  - Aural cues – don't need to look at the string, you can hear it
  - Visual cues – don't need to hear the whirling sound, you can see it

Zen of dangling string

- The dangling string is embedded into the environment
- Does not require constant attention
- Has a purpose (easily check amount of network traffic)

What makes them tick?

How are such ubiquitous computing systems made?

What is required for creating such systems?

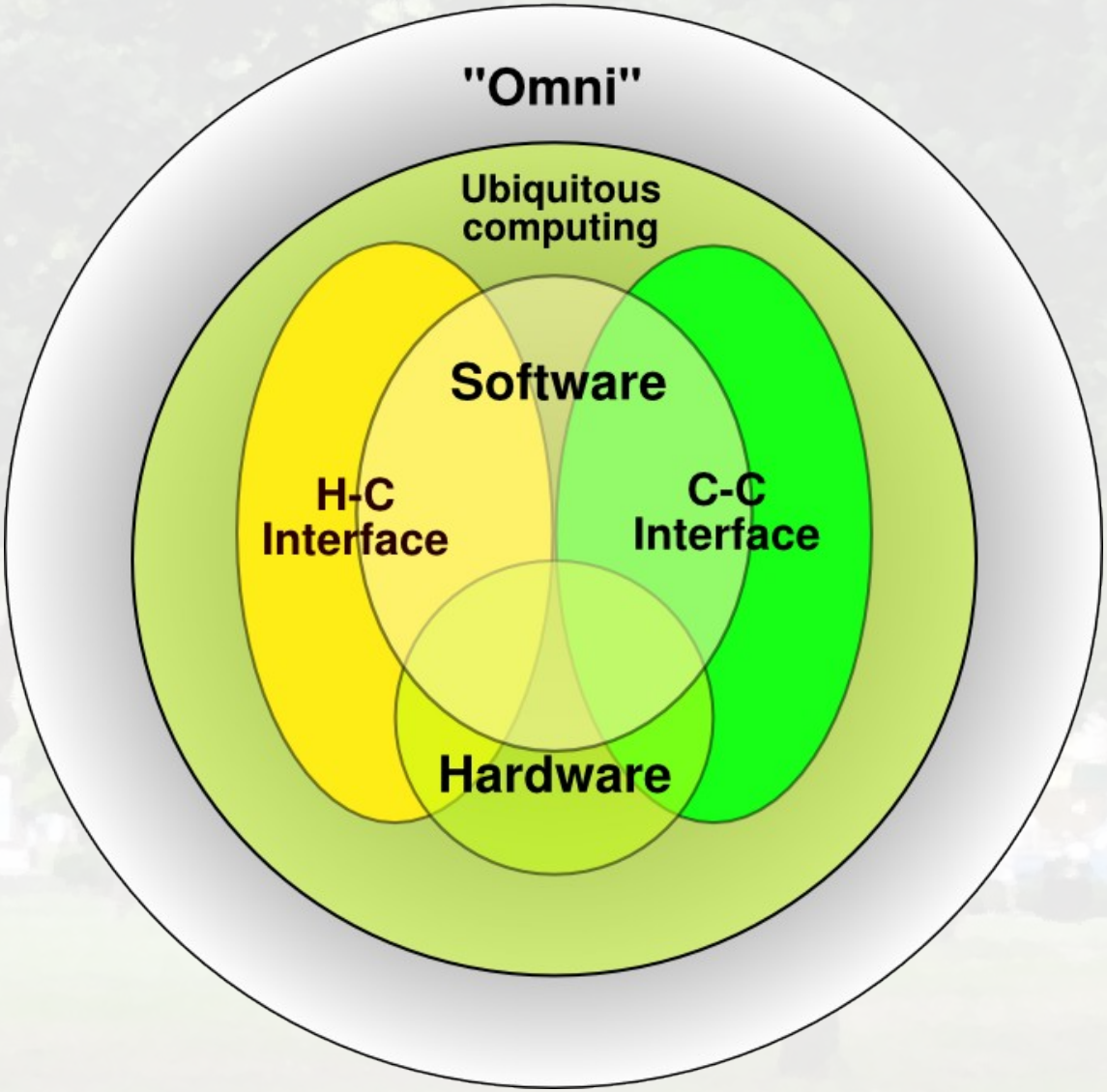
High-level view of building blocks 1

- Human-computer interface
  - Human ↔ computer
- Computer-computer interface
  - Computer ↔ computer
- Software support
  - The glue which binds all together
  - “The mind”

High-level view of building blocks 2

- Hardware
  - Environment ↔ computer
  - “The body”
- “Omni”
  - Concepts which apply (almost) everywhere at all times, regardless of the application domain
  - Privacy, security, power efficiency, etc.

Graphical view of the building blocks



Inside the building blocks... 1/3

- **Human-computer interface**
  - Human-computer interaction
  - Multimodal interfaces, tangible interfaces
  - Context awareness, context adaptation
  - Personalization
  - Augmented reality
- **Computer-computer interface**
  - Distributed computing
  - Peer to peer, ad-hoc networking, ...

Inside the building blocks... 2/3

- **Software support**
  - Adaptation, reasoning, autonomy, interpreted languages, data collection, data mining, object technologies, virtual machines, ...
- **Hardware**
  - Batteries, sensors, processors, displays, memories, ...

Inside the building blocks… 3/3

- **“Omni”**
  - Security, privacy, power efficiency, architectures, algorithms, …
  - Automation!
  - Common sense
- And so on, and so on, and so on, and so on

Some sub-areas in more detail

- Human-computer interaction
- Context-awareness and adaptation
- Distributed computing
- Software
- “Omni”

Human-computer interaction 1/2

- Multimodality – many interaction modes which utilize different human senses: sound input/output, visual i/o, touch i/o, etc.
- Enhancing the traditional 2D windowing-based user interfaces
- Other radical, new ways

Human-computer interaction 2/2

- Tangible interfaces – using physical things to manipulate digital things. Examples:
  - Tangible object = e.g. the lamp on your desk
  - Squeeze a soft cube to activate “night mode” of your bedroom
  - Fingertip(s) tracked by laser. User needs not wear extra gear nor carry a stylus – your finger is enough (Cassinelli, Perrin, Ishikawa)

Context awareness and adaptation

- The computer “knows” where the user is and what the user is doing, and when:
  - “Traveling”, “at a meeting”
  - “Waiting for the bus”
  - “Spaced out in the lobby after lunch”
- In other words, computer is aware of user's **context**
- The computer can use this information to behave in an intelligent way, to **adapt** to the user's behaviour or situation

Distributed computing 1/2

- Computers may need to communicate with each other
- For example, to exchange sensor data (door informs lights)
- Or to negotiate usage of meeting room resources
  - Resource being e.g. video projector
  - No cables, wireless access, no human intervention, automated discovery and resource reservation

Distributed computing 2/2

- User might move around to an area of different network technology, operator, coverage, etc.
  - Seamless connectivity needed
- Related things: protocols, structured data, metadata, security, etc.
- Peer-to-peer and ad-hoc networking:
  - No servers needed, no network infrastructure needed

Software 1/2

- Software exists **everywhere** within the area of ubiquitous computing, for example:
  - Device logic
  - Frameworks, common APIs
  - Protocol implementations, parsing, codecs, ...
  - Algorithm implementations

Software 2/2

- Logic of shutting down certain areas of the device to save battery life
- Reasoning about the user's context for better behaviour
- (Adapting) software architectures for more flexible devices
- Data mining to aid in reasoning and user behaviour analysis
- And so on!

“Omni” examples

- Privacy and security aspects
- Usage of efficient algorithms
- Device limitations
  - Battery life, memory, size, environment (e.g. underwater), ...
- Architecture and design of the devices
- Environmental aspects
  - E.g. don't deploy millions of devices with leaking super-toxic batteries

Dangers of ubiquitous computing 1/2

- Computers and computing everywhere: could we end up with “computer pollution”?
- What to do with old, aging computing devices either embedded into the environment, or otherwise found “everywhere”?
  - Easier to throw away old devices instead of upgrading them?

Dangers of ubiquitous computing 2/2

- Danger of ubiquitous surveillance: the “Big Brother -society”
  - Your house watches your every move
- Danger of (even more) ubiquitous advertising: the “spam-society”
- There's no doubt more danger scenarios...

Art or science? Or both? 1/2

- Artificial noise-sensitive flowers in meeting rooms. Too much noise makes the flowers wither.
- Tag **any** object (using object's weight) and use it to invoke actions in the computer. E.g. frisbee bound to open folder of holiday photos
  - "Users displayed more action during computing, reaching across desks and crossing rooms."

Art or science? Or both? 2/2

- "The You're In Control system uses computation to *enhance the act of urination*. Sensors in the back of a urinal detect the position of impact of a stream of urine, enabling the user to play interactive games on a screen mounted above the urinal."

Build tools for humans 1/2

- As an umbrella term, “ubiquitous computing” covers quite much from different fields of research, thus
- Weiser's vision requires **a multi-disciplinary approach,** which means also that…

Build tools for humans 2/2

- **...technical and non-technical disciplines** should both be included in the research, which means to
- **not** build *“toys for nerds”* **nor** *“art installations”* but rather
- **to build tools for humans.**

Thank you!

“Our computers should be like our childhood: an invisible foundation that is quickly forgotten but always with us, and effortlessly used throughout our lives.” (Weiser)